Rare Earth Elements

An Overview of Supply Chain Issues

Produced By

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   ○ Applications

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Disclaimer: This presentation should not be treated as an exhaustive or latest overview of the rare earth supply chain.
Introduction to Rare Earth Elements

17 total:
- **Light**
- **Medium**
- **Heavy**

- Rare is a misnomer. To economically process is “rare”
- Radioactivity typical around deposits (thorium)
Total rare earth mine production was 210,000 tons in 2019. However, these figures do not account for illegal production in China estimated to exceed 40,000 tons per annum.
Select REE Defense Applications

MILSTAR & Successor Programs
M1 Abrams
Electromagnetic Railgun
JDAM
AEGIS Combat System
Night Vision Googles
Select REE Energy and Commercial Applications

- Compact Fluorescent Light Bulbs
- Automotive / Industrial Motors
- Electric / Hybrid Vehicles
- HDDS
- Televisions
- Wind Turbines
- Fluid Catalytic Cracking in Petroleum Refining

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Simplified Supply Chain

- Ore is mined and REE minerals concentrated, usually at mine site
  - Mineral concentrate is processed to remove impurities
- Oxide preparation historically requires significant investment (as much as $500 million or $20-40k per MT in planned output), significant energy, and environmental mitigation
- Metal production is dominated by China
- Magnet production is dominated by China with Japanese and U.S. sources for SmCo and NdFeB
- Some alloy and magnet production in the U.S., but small by worldwide standards
REEs and the Defense Supply Chain

Chinese Exports

Toyota, Nissan, Honda, & GM have moved R&D and RE-intensive electric vehicle engine production facilities to China since 2011

End Product: RE Magnets

Supply Chain

Magnet Manufacturer

Magnet Distributor/Fabricator

OEM/Prime

Major Subcontractor

US Military Customer

Systems Integration

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NdFeB Magnet Supply Chain

Oxides

 Metals, Alloys, Powders

NdFeB Magnet Manufacturer

Potentially Supply Chain Reliant on Chinese REO

Beijing Jingci Magnetism Technology
Zhejiang Tinnau
Ningbo Co-Star Material High Tech
Shin Etsu

San Huan New Material High-Tech
Advanced Technologies & Materials
Hitachi Metals
Urban Mining Company

Thinova
Ningbo Yunshen
Vacuumschmelze GmbH

Ningbo Lihe
Integrated Magnetics
Ningbo Xionghai Magnetics

Dexter Magnetic Technologies
Force Field
KJ Magnetics
Allstar
Quadrant
Dura Magnetic
Adams
Magnetic Component Engineering
Magnet Sales
Stanford Magnetics
Compass Magnets & Components

Dura Magnetic
Integrated Magnetics
Ningbo Lihe Permanent Magnetic Materials
Ningbo Xionghai Magnetics

75% Global Production
Proposed Production

NdFeB Magnet Distributor & Fabricator

(Sales from Distributors or Manufacturer-direct)

U.S. Customer

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<table>
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<tr>
<th>Domestic and Allied Producers (Ores &amp; Concentrates)</th>
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<tr>
<th>Location</th>
<th>Company Name</th>
<th>Industry Perception</th>
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<tbody>
<tr>
<td>Mount Weld, Australia and Kauntan, Malaysia (Lynas Corp)</td>
<td>Currently in operation. Largest non-Chinese REE oxide producer. Resource skews “light”. Kuantan facility has prior history of radioactive contamination with local popular and government support lacking, leading to production delays.</td>
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<tr>
<td>Bokan Mountain, AK (Ucore Rare Metals)</td>
<td>Possesses proprietary Rapid SX technology to effectively separate REEs. Still undeveloped. Resource skews heavy, significant State of Alaska financial support.</td>
<td></td>
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<tr>
<td>Bear Lodge, WY (Rare Element Resources)</td>
<td>U.S. ownership. Skews “light.” Still undeveloped.</td>
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<tr>
<td>Round Top, TX (Texas Mineral Resources Corp)</td>
<td>Utilizes Continuous Ion Exchange (CIX) process. Still undeveloped.</td>
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Please note that these brief profiles on current and prospective REE producers are not intended to be a complete analysis of each project.
Domestic and Allied Producers (Oxide)

Lynas Corp, Kuantan, Malaysia

- Industry Perception: Largest source of high purity rare earth oxide outside China. Facility has a prior history of radioactive contamination. Government issuance of three-year facility permit could limit risk of production delays caused by prior permitting issues.

Lynas Corp/Blue Line Corp (TX) joint venture


NPM Silmet AS, Estonia (Neo Materials)

- Industry Perception: Parent company (Neo Materials) relies on its Chinese operations. Environmental concerns. Lacks sufficient waste storage required to store radioactive byproduct in order to continue production.
Domestic and Allied Producers (Metal)

**Eutectix Corp, Troy, MI/Tolleson, AZ**
- Industry Perception: Has limited equipment available. Exited rare earth market after Molycorp bankruptcy.

**Materion Corp, Mayfield Heights, OH**

**Less Common Metals, United Kingdom**

**NPM Silmet AS, Estonia (Neo Materials)**

Smaller rare earth metal producers are located in Brazil and Thailand as well, but they provide only a small part of the supply chain.
Domestic Producers (Alloy)

Eutectix Corp, Troy, MI/Tolleson, AZ

- Industry Perception: Has equipment already available. Exited rare earth market after Molycorp bankruptcy and has expressed desire to avoid further rare earth exposure.

Electron Energy Corp, Landisville, PA


Urban Mining Corp, San Marcos, TX

- Industry Perception: Recycling technology can provide “closed-loop” NdFeB alloys without Chinese feedstock. Still developing commercial-scale production. Only provides NdFeB.
Producers (SmCo Magnets)

Electron Energy Corp, Landisville, PA


Arnold Magnetics, Rochester, NY


Vacuumschmelze, Germany

Urban Mining Company, San Marcos, TX

- Industry Perception: Awarded contract from DPA Title III Office to produce NdFeB magnets. Recycling technology allows “closed-loop” production not dependent on Chinese feedstock.

Hitachi Corp, Japan

- Industry Perception: Current non-Chinese supplier of NdFeB magnets. History of aggressive behavior towards other Western attempts to develop NdFeB sources. Not transparent or open about sourcing.

Vacuumschmelze, Germany

- Industry Perception: Current U.S. military supplier for NdFeB. Only compliant for one grade of NdFeB and for sales of this grade in large quantities. Dependent on Hitachi patent license. Commercial focus.
Concerns for U.S. Industry

- Limited stable or non-Chinese ore and oxide supply
  - Only U.S. producer is partially Chinese-owned and reliant on foreign processing of its U.S. mined material
  - Only one non-Chinese producer that cannot supply the entire market alone
- Limited number of U.S. magnet suppliers
  - Only 1 U.S. facility for SmCo
  - First U.S. NdFeB magnet manufacturer coming online
- Limited U.S. alloy capacity
  - Only 2-3% of global alloy capacity, and dependent on foreign markets and supply chains
- No U.S. metal manufacturing
  - Industry is still almost entirely concentrated in China
Government Statements on REEs

Ellen Lord:
- **August 26, 2019 Press Briefing:** "We have been focused on rare earths for quite some time...The challenge is really the processing of them and having facilities to do that. Because quite often, China mines them elsewhere and brings them back to China to process them...We're concerned about any fragility in the supply chain, and especially where an adversary controls the supply."
- **April 2018:** Lord said that US reliance on China for critical minerals is "quite alarming...we have an amazing amount of dependency on China. We are sole sources for rare earth minerals, some energetics, different things. This is a problem for us as we move forward."

Mike Pompeo:
- **March 26, 2020 Interview:** "When it comes to important material things that the United States needs for its own security...I would add rare earth minerals, I would add a host of other things that are really central to American security. We need to fundamentally review our supply chains and make sure that we know those supply chains and have control over them for moments just like this."
- **September 26, 2019:** "...we must also pursue new sources of these critical minerals."

Letter from Senators to Secretary Esper:
- **April 24, 2020:** “It is clear that our dependence on China for vital rare earths threatens our U.S. manufacturing and defense industrial base. As the October 2018 Defense Industrial Base (DIB) Report states: ‘China represents a significant and growing risk to the supply of materials deemed strategic and critical to U.S. national security.’ [...] Ensuring a U.S. supply of domestically sourced rare earths will reduce our vulnerability to supply disruptions that poses a grave risk to our military readiness.” (Senators McSally, Cruz, Barrasso, Cotton, Enzi, and Gardner).
Government Rare Earth Studies

- **USGS** and **Department of Interior** – Rare Earths are “critical minerals”
- **DLA-SM** – Rare earths are critical and in shortfall
- **Department of Energy** – Rare earths are critical
- **GAO** – Reporting on rare earths could be improved
- Bottom line: Government has studied the rare earth issue for more than a decade and come to a consensus position — **rare earths are critical materials!**
The FY19 NDAA included the first law prohibiting purchase of Chinese rare earth magnets, now codified at 10 U.S.C. §2533c. Requires DoD to avoid purchasing magnets “produced” in China:
- This applies to the sintering or bonding process — allows use of Chinese ores, concentrates, and oxides (due to lack of alternatives)
- Incentivizes development of American solutions
Disrupts the distributor/fabricator model, which depends on magnets manufactured in China and then “cut” in U.S. or Japan
- Incentivizes recycling of magnets within the U.S.
2020 Rare Earth Policy Developments

- 2019: Five Presidential Determinations declaring REEs critical to national security and authorizing Defense Production Act (DPA) Title III investment to establish capabilities for:
  1. Light Rare Earth Elements (LREE)
  2. Heavy Rare Earth Elements (HREE)
  3. Rare Earth Metals and Alloys
  4. NdFeB Rare Earth Magnets
  5. Samarium Cobalt Rare Earth Magnets

- 2020: DoD issues two HREE contracts for REE production:
  - Lynas / Blue Line joint venture
  - MP Materials

- HREE contracts sparked concern from members of congress over companies having Chinese investment and relying on raw material imports

- Also in 2020: DoD awards Urban Mining Company DPA contract to produce NdFeB Rare Earth Magnets
Future Outlook

- Rare earth investment market has not recovered from the bankruptcy of Molycorp, even with MP Materials taking over its former Mountain Pass mine
  - Market awaits MP Materials’ forthcoming IPO
- Lynas is the only allied company mining and refining oxide
- Recycling offers intriguing possibilities, but currently only projected to apply to one set of magnets
- China unlikely to give up its monopoly position willingly, and will likely continue to use its power to push in to higher-value downstream applications
**U.S. Government Options**

**DPA Investment**
Targeted investments can reinvigorate the supply chain both on selected projects and in adjacent sectors. 2533c creates important U.S. demand to sustain entry of new domestic NdFeB suppliers into the market.

**WTO Action**
Counterproductive the first time, probably not an effective strategy.

**Substitution**
Low-hanging fruit gone, and has not produced significant results.

**Continued Protection for Non-Chinese Suppliers**
- SmCo protected under 2533b and 2533c
- NdFeB protected under 2533c
- Non-magnet REE uses still mostly unprotected
Green & Co. Recommendations

1. Fully fund DPA Title III account for REE projects
2. Invest in right domestic sources for HREEs
   - Lynas/Blue Line reliant on foreign feedstock from Australia
   - MP Materials lacks sufficient HREEs in ore body to serve
3. Release pending “Rare Earth Metals and Alloys” DPA Title III solicitation
4. Establish buffer stocks or stockpile REE concentrate and REE master alloy and/or magnets
5. Support tax incentives for development of domestic production of REEs
Conclusion

- Rare earths are critical to national security
- Despite some progress since 2010, China remains dominant in the supply chain
- The private sector cannot and will not solve U.S. military REE supply chain insecurity on its own
- But innovative solutions to portions of the supply chain do exist
- Government must find ways to get involved, but there are no quick fixes
- Government should prioritize truly domestic projects for investment
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